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US Army Research Laboratory

Ballistic Evaluation of 6055 Aluminum

by Denver B Gallardy

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Weapons and Materials Research Directorate, ARL

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14. ABSTRACT
The US Army Research Laboratory (ARL) evaluated the ballistic performance of aluminum alloy (AA) 6055-T651 produced by Alcoa as part of a Defense Acquisition Challenge Program. Ballistic evaluation was performed using armor-piercing and fragment-simulating projectiles to determine the V_{50} ballistic-protection limit (V_{50}) for various thicknesses of material. The V_{50} was then compared to other ballistic-grade aluminum alloys, namely AA6061 and AA7039. The results of these experiments were used to derive the acceptance tables for AA6055 included in the updated military specification, MIL-DTL-32262A (MR).

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1. Introduction

In 2012, a Defense Acquisition Challenge (DAC) Program proposal was submitted to the Office of the Secretary of Defense (OSD) to provide improved armor-plate materials for production and repair of existing or new aluminum-based monocoque armored-vehicle hulls such as those of M2 Bradley Infantry Fighting Vehicles. Also in 2012, the Aluminum Association assigned a new 6XXX-series alloy designation to Alcoa for aluminum alloy (AA) 6055, granting it full commercial availability as rolled plate from Davenport, Iowa. AA6055 remains under patent protection and is solely manufactured by Alcoa. AA6055 was confirmed as having greater mechanical properties than the AA6061 alloy and therefore, became the basis for a fiscal-year 2012, OSD-funded DAC program to fully validate and ultimately transition AA6055 for availability as a weldable armor plate in US acquisition. The ballistics goal of this program was to verify that AA6055-T651 met or exceeded the performance of AA6061-T651.[1]

Several thicknesses of 6055-T651 were provided to the US Army Research Laboratory (ARL) by Alcoa. Table 1 is a summary matrix of the tested thicknesses subjected to impacts from various munitions including armor-piercing (AP) and fragment-simulating projectiles (FSPs). Additionally, Table 2 provides the required chemistries for AA6055 as well as other common aluminum-armor alloys.

Table 1 Test matrix for AA6055 indicating the number of plates tested

Nominal Plate Gage (mm)	0.30-cal APM2 30° Obliquity	0.30-cal APM2 0° Obliquity	0.50-cal APM2 0° Obliquity	0.50-cal FSP 0° Obliquity	20-mm FSP 0° Obliquity	14.5-mm BS41 0° Obliquity
12.70	3	…	…	…	…	…
19.05	2	2	…	2	…	…
25.40	…	3	…	3	3	…
38.10	…	5	5	…	4	…
50.80	…	…	5	…	5	…
63.50	…	…	2	…	…	…
76.20	…	…	1	…	…	1

Table 2 Chemistry of AAs, weight-percent ranges[2]

Element	2139	2195	2519	5083	6061	6055	7039	7085
Copper	4.5–5.5	3.70–4.30	5.30–6.40	0.10 max	0.15–0.40	0.50–1.0	0.10 max	1.3–2.0
Iron	0.15 max	0.15 max	0.30 max[a]	0.40 max	0.70 max	0.30 max	0.40 max	0.08 max
Lithium	…	0.80–1.20	…	…	…	….	…	…
Chromium	0.05 max	…	…	0.05–0.25	0.04–0.35	0.20–0.30	0.15–0.25	0.04 max
Manganese	0.20–0.60	0.25 max	0.10–0.50	0.40–1.0	0.15 max	0.10 max	0.10–0.40	0.04 max
Magnesium	0.20–0.80	0.25–0.80	0.05–0.40	4.0–4.90	0.8–1.2	0.70–1.1	2.30–3.30	1.2–1.8
Silicon	0.10 max	0.12 max	0.25 max[a]	0.40 max	0.40 –0.80	0.60–1.2	0.30 max	0.06 max
Titanium	0.15 max	0.10 max	0.02–0.10	0.15 max	0.15 max	0.10 max	0.10 max	0.06 max
Zinc	0.25 max	0.25 max	0.10 max	0.25 max	0.25 max	0.55–0.90	3.50–4.50	7.0–8.0
Zirconium	…	0.08–0.16	0.10–0.25	…	…	…	…	0.08–0.15
Silver	0.15–0.60	0.25–0.60	…	…	…	…	…	…
Others (each)	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max
Others (total)	0.15 max	0.15 max	0.15 max	0.15 max	0.15 max	0.15 max	0.15 max	0.15 max
Aluminum	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder	Remainder

[a]The total weight percentage of the combination of silicon and iron cannot exceed 0.40%.

2. Experimental Procedure

The V_{50} is defined as the impact velocity at which the projectile is equally as likely to penetrate the target as it is to arrest. A 0.51-mm (0.020-inch) 2024 T3 aluminum witness plate is positioned 152 mm (6 inches) behind the target to determine the outcome of each shot. An impact is regarded as a complete penetration (CP), or loss, if the projectile or a resulting target fragment from impact creates a hole in the witness plate through which light can be observed. If an impact does not result in a CP, it is considered a partial penetration (PP), or win. In order to keep results as consistent as possible, only shots conforming to the following conditions were used to determine the V_{50}: The projectile must be unyawed; <2° of total yaw for AP rounds and <5° of total yaw for FSPs; and strike the target at least 2 projectile diameters from any previous impact or damage or the edge of the target. Total yaw is defined as the vector sum of the projectile's pitch and yaw. The V_{50} is calculated by the arithmetic mean of an equal number of CPs and PPs within an 18 m/s (60 ft/s) spread for a 2 + 2 V_{50}; a 27 m/s (90 ft/s) spread for a 3 + 3 V_{50}; and as small of a spread as attainable for a 5 + 5 V_{50}.[3]

Projectile velocities for the determination of the V_{50} were measured using one of 2 methods as shown in Fig. 1. The first method is an orthogonal flash X-ray system as described in detail by Grabarek and Herr,[4] which also measures pitch and yaw. The second method uses 3 infrared (IR) screens and a chronograph. The velocity is calculated using the first and third screens with the middle screen used to check for bad readings. The flash X-ray method was used in situations with projectiles that historically exhibit excessive yaw or if space did not allow for the use of the IR break screens. When the IR break screens and chronograph were used, the projectile velocity was corrected to the target-impact location using a correction factor based on an initial flash X-ray reading at the impact location. The correction was made using Eqs. 1 and 2 in lieu of utilizing air-drag factors:

$$\frac{(\text{x-ray velocity})}{(\text{chronograph velocity})} = (\text{correction factor}) \quad (1)$$

$$(\text{correction factor}) \times (\text{chronograph velocity}) = (\text{corrected velocity}) \quad (2)$$

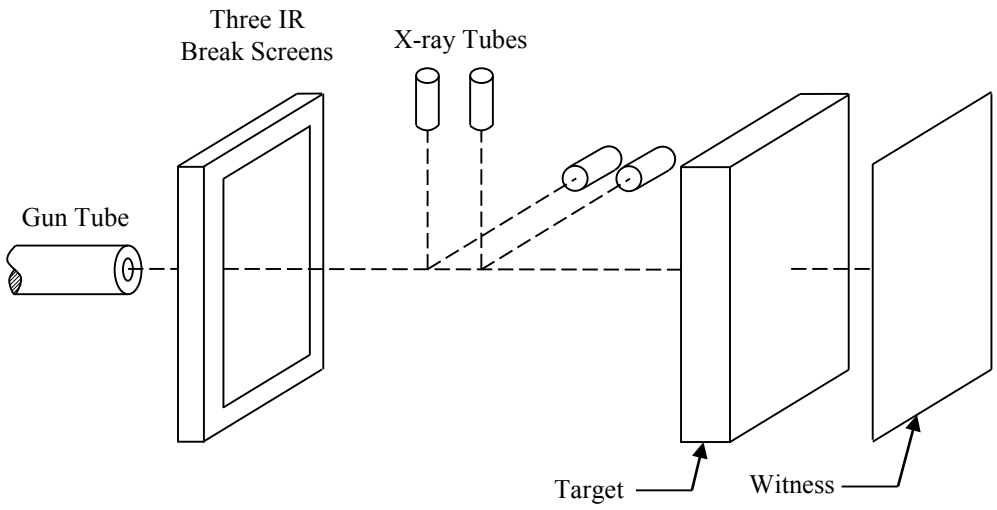

Fig. 1 Typical test setup

3. Test Projectiles

3.1 Armor-Piercing (AP) Projectiles

The US 0.30-cal. APM2 and 0.50-cal. APM2 and the Soviet 14.5-mm BS41 are the 3 AP projectiles that were used in this study. These projectiles are shown in Fig. 2. The APM2 projectiles have hardened steel cores with hardness of Rockwell C61–63 whereas the BS41 has a tungsten carbide core. The physical characteristic of these projectiles are listed in Table 3. Additionally, a few experiments were

repeated with the 0.30-cal. APM2 Test Parts Kit (0.30-cal kit) round. This round is a US Army-authorized replacement for the historical 0.30-cal. APM2 due to the near depletion of the 0.30-cal. APM2 supply.

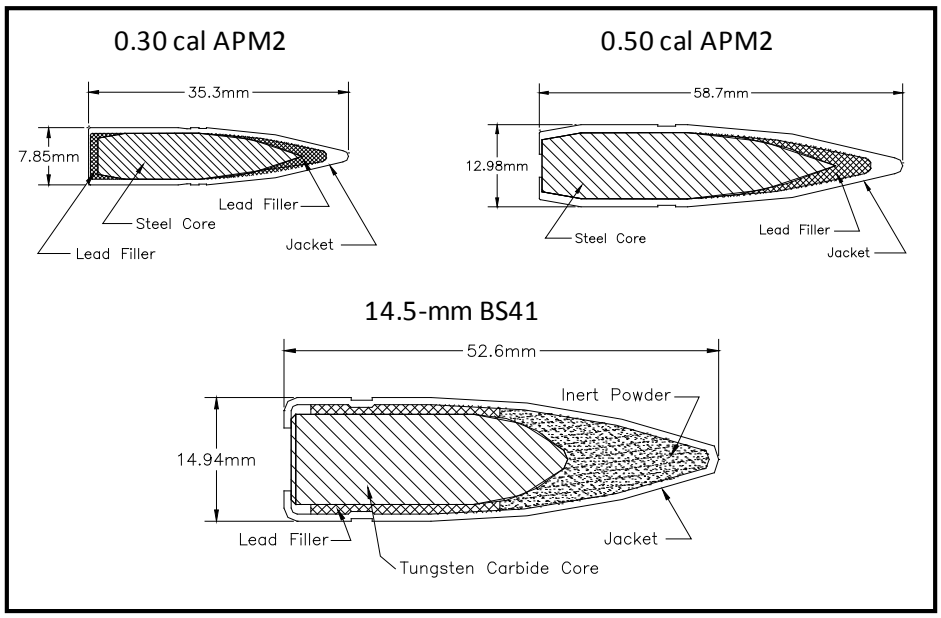

Fig. 2 AP projectiles

Table 3 AP projectiles' physical characteristics[5]

Projectile Type	Projectile			Core		
	Length (mm)	Diameter (mm)	Weight (g)	Length (mm)	Diameter (mm)	Weight (g)
0.30-cal. APM2	35.3	7.85	10.8	27.4	6.2	5.3
0.50-cal. APM2	58.7	12.98	45.9	47.5	10.9	25.9
14.5-mm BS41	52.6	14.94	63.2	32.3	10.9	37.9

3.2 Fragment-Simulating Projectiles (FSP)

FSPs (Fig. 3) are a family of projectiles that are flat-nosed, right circular cylinders manufactured to MIL-DTL-46593B (MR).[6] These projectiles are used in material evaluations and acceptance testing to simulate performance against fragments produced from improvised explosive devices and artillery. Both 0.50-cal. and 20-mm FSPs were used for the evaluation of AA6055.

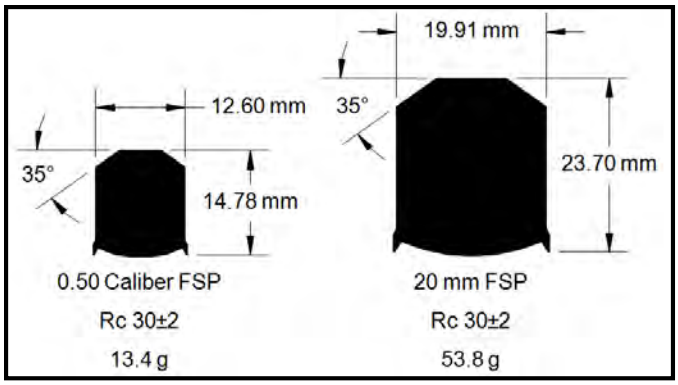

Fig. 3 FSP projectiles

4. Results and Analysis

The test results are summarized in Tables 4–9. The individual shot records are provided in Appendix A. Additionally, ballistic data obtained by the US Army, Aberdeen Test Center (ATC)[7] are included in Appendix B.

Table 4 0.30 cal. APM2, 30° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	(mm)	(in)	(mm)	(in)	(kg/m^2)	(lb/ft^2)	(m/s)	ft/s	(m/s)	(ft/s)
521–782	12.70	0.50	12.93	0.509	35.07	7.18	482	1582	8	26
521–782[a]	12.70	0.50	12.93	0.509	35.07	7.18	479	1571	10	34
521–792	12.70	0.50	12.95	0.510	35.13	7.20	479	1573	7	24
521–792	12.70	0.50	12.98	0.511	35.20	7.21	474	1556	9	29
521–802	19.05	0.75	19.02	0.749	51.60	10.57	610	2001	10	32
521–812	19.05	0.75	19.08	0.751	51.74	10.60	609	1998	10	33
521–812[a]	19.05	0.75	19.08	0.751	51.74	10.60	614	2016	8	25

[a]0.30-cal kit

Table 5 0.30 cal. APM2, 0° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	mm	in	mm	in	kg/m^2	lb/ft^2	m/s	ft/s	m/s	ft/s
521–802	19.05	0.75	19.02	0.749	51.60	10.57	539	1770	11	37
521–812	19.05	0.75	19.08	0.751	51.74	10.60	537	1762	6	20
521–812 [a]	19.05	0.75	19.08	0.751	51.74	10.60	531	1743	6	21
521–822	25.40	1.00	25.25	0.994	68.48	14.03	618	2028	10	34
521–822 [a]	25.40	1.00	25.25	0.994	68.48	14.03	620	2033	6	21
521–832	25.40	1.00	25.68	1.011	69.65	14.27	634	2079	9	31
521-842	25.40	1.00	25.37	0.999	68.82	14.10	630	2067	8	25
521–871	38.10	1.50	37.97	1.495	102.99	21.09	798	2618	5	17
521–871[a]	38.10	1.50	37.97	1.495	102.99	21.09	800	2626	9	28
521–872	38.10	1.50	37.97	1.495	102.99	21.09	788	2585	8	26
521–881	38.10	1.50	38.02	1.497	103.13	21.12	803	2634	9	28
521–882	38.10	1.50	38.10	1.500	103.34	21.17	809	2654	8	25
521–892	38.10	1.50	38.05	1.498	103.20	21.14	808	2651	8	27

[a]0.30-cal kit

Table 6 0.50 cal. APM2, 0° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	(mm)	(in)	(mm)	(in)	(kg/m^2)	(lb/ft^2)	(m/s)	(ft/s)	(m/s)	ft/s
521–871	38.10	1.50	37.92	1.493	102.85	21.07	585	1918	7	24
521-872	38.10	1.50	37.95	1.494	102.92	21.08	584	1915	7	24
521–881	38.10	1.50	38.02	1.497	103.13	21.12	584	1917	9	29
521–882	38.10	1.50	38.07	1.499	103.27	21.15	600	1969	9	28
521–892	38.10	1.50	38.05	1.498	103.20	21.14	603	1977	11	36
521–901	50.80	2.00	50.22	1.977	136.20	27.90	687	2254	5	15
521–902	50.80	2.00	45.47	1.790	123.31	25.26	686	2251	9	29
521–911	50.80	2.00	50.77	1.999	137.71	28.21	704	2309	5	16
521–921	50.80	2.00	50.90	2.004	138.06	28.28	697	2286	6	19
521–922	50.80	2.00	50.29	1.980	136.40	27.94	694	2278	6	21
521–941	63.50	2.50	63.50	2.500	172.23	35.28	797	2615	7	24
521–942	63.50	2.50	63.17	2.487	171.33	35.09	814	2671	8	27
521–951	76.20	3.00	74.12	2.918	201.02	41.17	906	2974	8	25

Table 7 14.5-mm BS41, 0° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	(mm)	(in)	(mm)	(in)	(kg/m^2)	(lb/ft^2)	(m/s)	ft/s)	(m/s)	(ft/s)
521–951	76.20	3.00	74.12	2.918	201.02	41.17	839	2752	10	32

Table 8 0.50 cal. FSP, 0° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	(mm)	(in)	(mm)	(in)	(kg/m^2)	(lb/ft^2)	(m/s)	(ft/s)	(m/s)	(ft/s)
521–802	19.05	0.75	19.08	0.751	51.74	10.60	575	1888	4	13
521–812	19.05	0.75	19.13	0.753	51.87	10.62	588	1929	6	19
521–822	25.40	1.00	25.17	0.991	68.27	13.98	926	3037	9	28
521–832	25.40	1.00	25.65	1.010	69.58	14.25	949	3114	8	27
521–842	25.40	1.00	25.35	0.998	68.75	14.08	918	3012	9	28

Table 9 20-mm FSP, 0° obliquity V_{50} ballistic limits for AA6055

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		V_{50}		Standard Deviation	
	(mm)	(in)	(mm)	(in)	(kg/m^2)	(lb/ft^2)	(m/s)	(ft/s)	(m/s)	(ft/s)
521–822	25.40	1.00	25.17	0.991	68.27	13.98	442	1449	8	26
521–832	25.40	1.00	25.45	1.002	69.03	14.14	418	1372	5	16
521–842	25.40	1.00	25.40	1.000	68.89	14.11	422	1384	5	17
521–871	38.10	1.50	37.92	1.493	102.85	21.07	811	2661	8	26
521–881	38.10	1.50	38.02	1.497	103.13	21.12	817	2681	4	12
521–882	38.10	1.50	37.92	1.493	102.85	21.07	782	2565	7	24
521–892	38.10	1.50	38.10	1.500	103.34	21.17	741	2432	8	25
521–901	50.80	2.00	50.72	1.997	137.57	28.18	1215	3985	9	30
521–902	50.80	2.00	50.39	1.984	136.68	27.99	1199	3935	9	31
521–911	50.80	2.00	50.77	1.999	137.71	28.21	1202	3943	7	24
521–921	50.80	2.00	50.90	2.004	138.06	28.28	1169	3836	5	16
521–922	50.80	2.00	50.55	1.990	137.09	28.08	1175	3854	5	17

The results of the ballistic evaluation are compared directly against the acceptance curves of AA6061 in MIL-DTL-32262 and AA7039 in MIL-DTL-46063H[8] for a higher-performing, 7XXX-series reference point. Figures 4–8 show the AA6055 test data collected by ARL and ATC as compared to the other specifications. The data displayed are the V_{50} as a function of the plate thickness. To allow for a fair comparison against the existing specifications, a line depicting the V_{50} -2σ was plotted against the acceptance specs. This line represents a V_{02} rather than a V_{50}. To ensure successful protection at a given thickness, the lower band of the 2σ distribution (V_{02} line) is used to define minimum-acceptable performance. A V_{50} falling below this line is considered unacceptable. For comparison purposes it should also be noted that the plates are compared on a thickness basis to be consistent with the specifications; however, the densities of the alloys vary slightly.

Both AA6061 and AA6055 have a density of 2.71 g/cm^3 whereas AA7039 has a density of 2.74 g/cm^3.

As can be observed in the plots (Figs. 4–6), the AP performance for AA6055 is significantly higher than the existing AA6061 acceptance requirements. In fact, the data points approach the performance of AA7039 and in some cases actually exceed the AA7039 requirement. For the 0.30-cal. APM2 at 30° obliquity, the V_{50} -2σ line falls above the AA7039 spec for plate thicknesses less than 0.675 inches.

Turning to the FSP performance (Figs. 7 and 8), it can be observed that the performance of 6055 continues to behave more like AA7039 than AA6061. The 0.50-cal FSP performance yielded several data points above the AA7039 specification and the V_{50} -2σ line fell slightly below the AA7039 specification. Similarly, for the 20-mm FSP, AA6055 exhibited a steeper performance curve like AA7039 as compared to the shallower AA6061 curve. Also, like AA7039 the 20-mm FSP performance drops below the AA6061 performance for thinner plates. This transition occurs at 32.64 mm (1.285 in) for AA6055, which is slightly higher than the 30.35 mm (1.195 in) transition of AA7039.

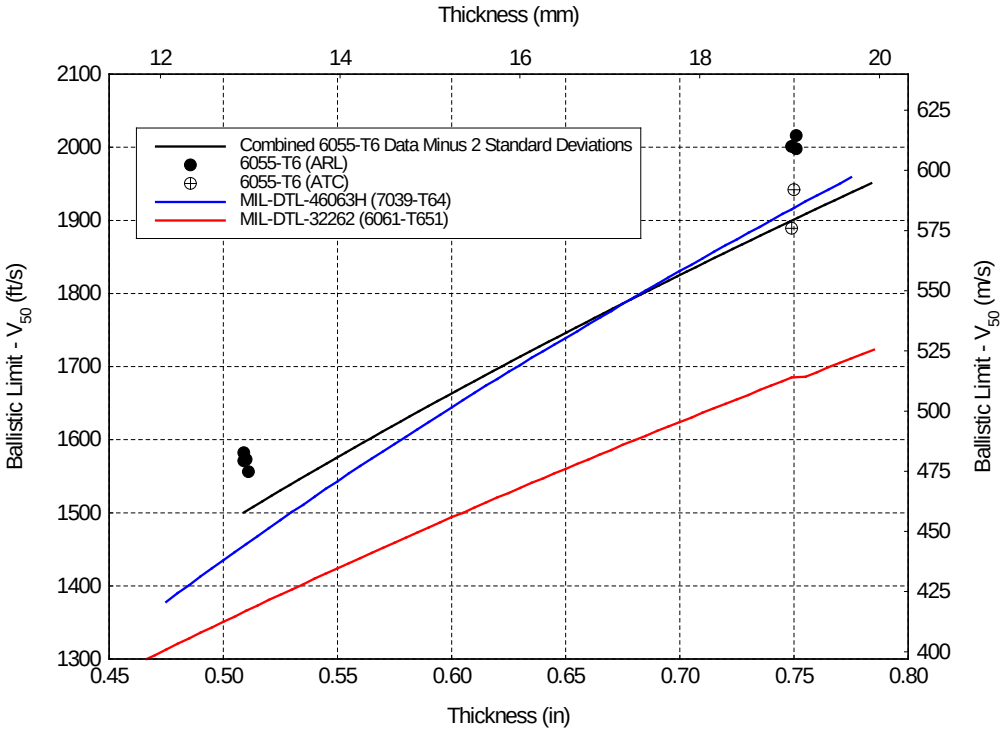

Fig. 4 Ballistic limit vs. thickness of AA6055 as compared to existing specs for the 0.30-cal APM2 at 30° obliquity

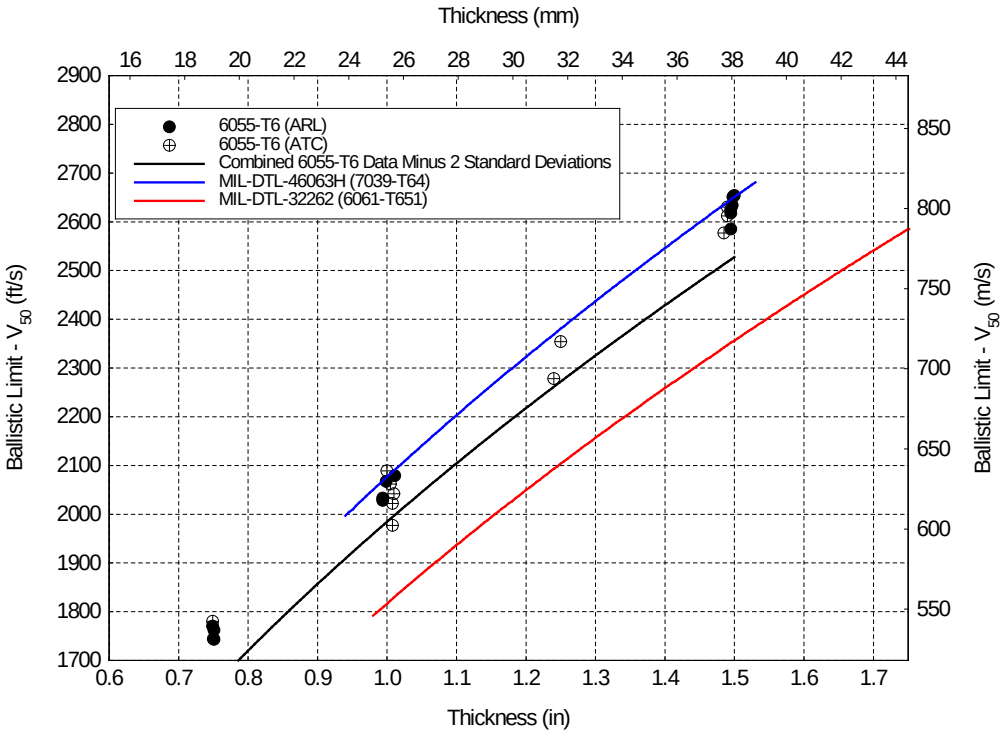

Fig. 5 Ballistic limit vs. thickness of AA6055 as compared to existing specs for the 0.30-cal APM2 at 0° obliquity

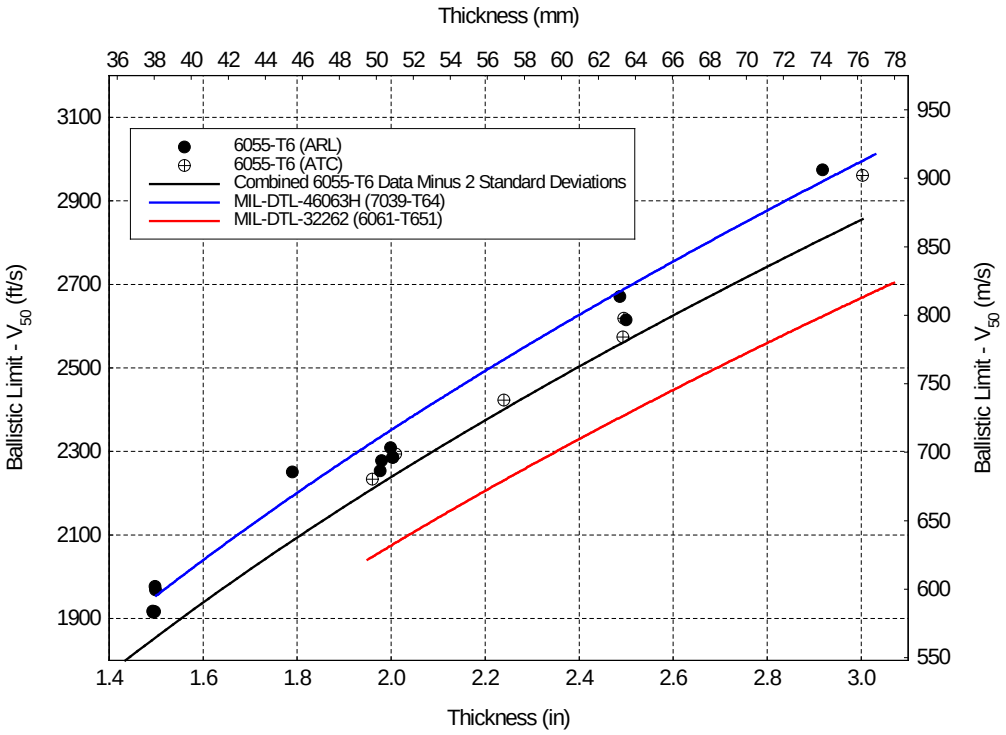

Fig. 6 Ballistic limit vs. thickness of AA6055 as compared to existing specs for the 0.50-cal APM2 at 0° obliquity

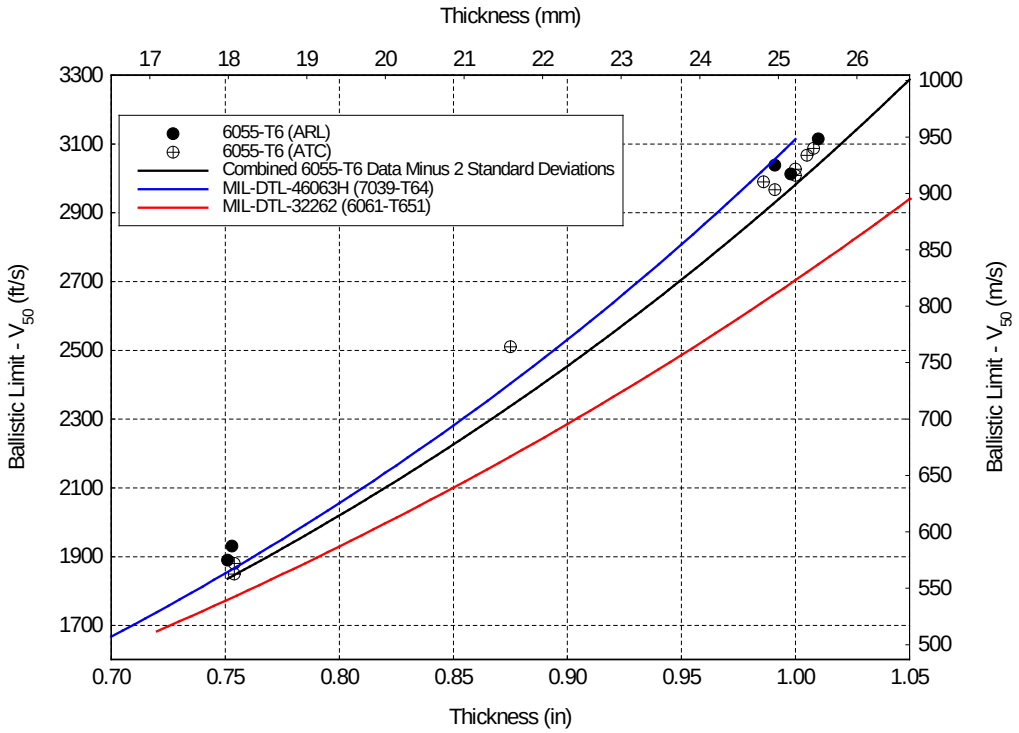

Fig. 7 Ballistic limit vs. thickness of AA6055 as compared to existing specs for the 0.50-cal FSP at 0° obliquity

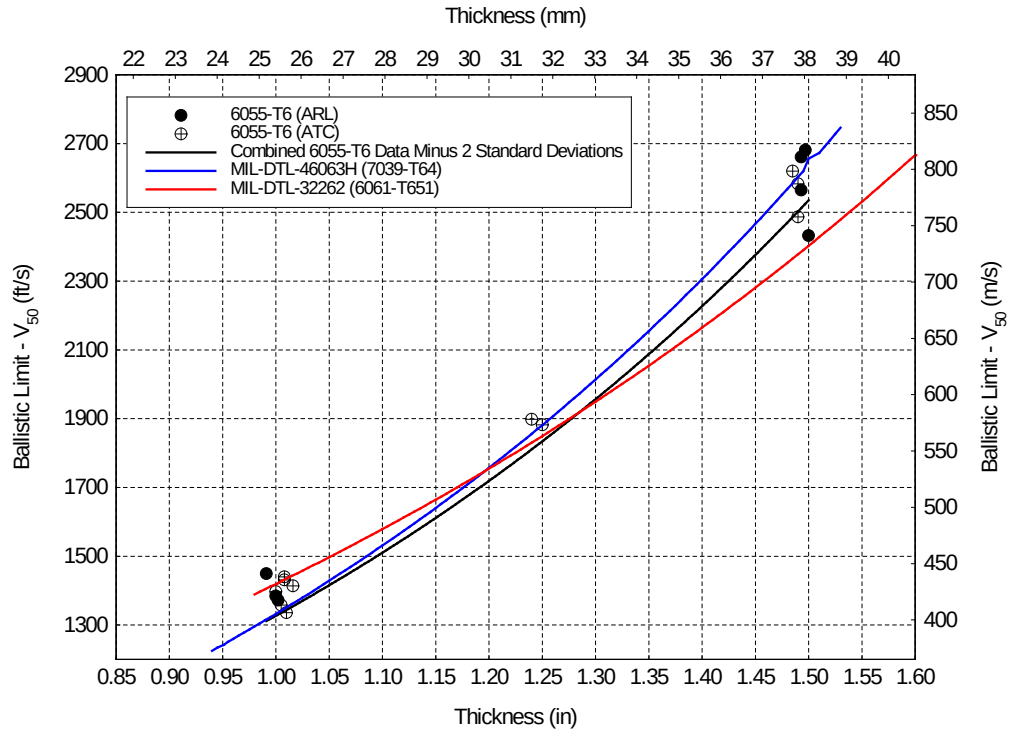

Fig. 8 Ballistic limit vs. thickness of AA6055 as compared to existing specs for the 20-mm FSP at 0° obliquity

The data collected by ARL, as well as data collected by ATC,[7] were then used to generate acceptance tables for MIL-DTL-32262A (MR). The acceptance velocities were calculated by fitting the V_{50} data minus 2 standard deviations with Eqs. 3 and 4 for AP and FSP projectiles respectively.[9,10]

$$V_A = 1000\sqrt{a + bt} \tag{3}$$

$$V_A = 1000e^{a+bt} \tag{4}$$

In the above equations V_A is the acceptance velocity, t is the actual thickness of the plate, and both a and b are constants of regression. Table 10 lists the constants of regression and the Pearson's R correlation coefficient for each projectile. The ballistic tables corresponding to the acceptance curves can be found in MIL-DTL-32262A (MR).

Table 10 Constants of regression for the acceptance curves for AA6055

Projectile Type	6055		
	a	**b**	**R**
0.30-cal AP, M2 at 30°	–0.626	5.65	0.969
0.30-cal AP, M2 at 0°	–0.961	4.90	0.988
0.50-cal AP, M2 at 0°	–1.26	3.14	0.981
0.50-cal FSP at 0°	–0.858	1.95	0.994
20-mm FSP at 0°	–1.01	1.29	0.987

5. Conclusions

A ballistic evaluation has been performed on AA6055 in the T651 temper. This report has compared the performance of AA6055 against existing mil-spec, aluminum-armor material, namely AA6061 and AA7039. AA6055 performed better that AA6061 against both AP and FSP projectiles. The only exception is 20-mm FSP performance below 1.285 inches, where AA6061 exhibits higher performance. This report has also documented the calculations used to derive the acceptance tables included in the updated military specification, MIL-DTL-32262A (MR).

6. References

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9. DeLuca E, Anctil A. Laminate armor for light combat vehicles. Watertown (MA): Army Materials Technology Laboratory (US); 1986 Apr. Report No.: MTL TR 86-14.

10. Van Caneghem R, Typanski D, Latham R. Appendix C: Ballistic testing of aluminum armor alloys – shock testing of weldments and specification data. Aberdeen Proving Ground, MD: Army Combat Systems Test Activity (US); 1986 Apr. Report No.: MTL TR 86-14.

Appendix A. Ballistic Test Data

This appendix appears in its original form, without editorial change.

0.30-cal APM2

Target:	**6055-T651**	Date:	**4/4/2013**
Plate Number:	**521-782**	Location:	**EF 106**
Thickness, in:	**0.509**		
Thickness, mm:	**12.93**		
Hardness, BHN:	**134**		
Obliquity:	**30°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1582 ft/s**	Number of Shots:	**4**
Std Dev:	**26 ft/s**	Spread:	**58 ft/s**
ZMR:	**16 ft/s**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1645	501	--	--	CP	No	12530	
1566	**477**	**--**	**--**	**CP**	**Yes**	**12531**	
1467	447	--	--	PP	No	12532	
1468	447	--	--	PP	No	12533	
1511	461	--	--	PP	No	12534	
1530	466	--	--	PP	No	12535	
1582	**482**	**--**	**--**	**PP**	**Yes**	**12536**	
1619	**493**	**--**	**--**	**CP**	**Yes**	**12537**	
1561	**476**	**--**	**--**	**PP**	**Yes**	**12538**	

Target:	**6055-T651**	Date:	**4/9/2013**
Plate Number:	**521-782**	Location:	**EF 106**
Thickness, in:	**0.509**		
Thickness, mm:	**12.93**		
Hardness, BHN:	**134**		
Obliquity:	**30°**		
Projectile:	**0.30 cal Kit**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1571 ft/s**		Number of Shots:	**6**
Std Dev:	**34 ft/s**		Spread:	**82 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1652	504	--	--	CP	No	12539	
1529	**466**	--	--	**PP**	**Yes**	**12540**	
1586	**483**	--	--	**CP**	**Yes**	**12541**	
1528	**466**	--	--	**PP**	**Yes**	**12542**	
1524	464	--	--	PP	No	12543	
1610	**491**	--	--	**CP**	**Yes**	**12544**	
1579	**481**	--	--	**PP**	**Yes**	**12545**	
1592	**485**	--	--	**CP**	**Yes**	**12546**	

Target:	**6055-T651**	Date:	**4/9/2013**
Plate Number:	**521-792**	Location:	**EF 106**
Thickness, in:	**0.510**		
Thickness, mm:	**12.95**		
Hardness, BHN:	**137**		
Obliquity:	**30°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1573 ft/s**		Number of Shots:	**4**
Std Dev:	**24 ft/s**		Spread:	**51 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1524	464	--	--	PP	No	12547	
1617	493	--	--	CP	No	12548	
1632	497	--	--	CP	No	12549	
1584	**483**	--	--	**CP**	**Yes**	**12550**	
1537	**468**	--	--	**PP**	**Yes**	**12551**	
1584	**483**	--	--	**PP**	**Yes**	**12552**	
1588	**484**	--	--	**CP**	**Yes**	**12553**	

Target:	**6055-T651**	Date:	**6/12/2013**
Plate Number:	**521-792**	Location:	**EF 106**
Thickness, in:	**0.511**		
Thickness, mm:	**12.98**		
Hardness, BHN:	**137**		
Obliquity:	**30°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1556 ft/s**		Number of Shots:	**6**
Std Dev:	**29 ft/s**		Spread:	**75 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1447	441	--	--	PP	No	12761	
1517	**462**	**--**	**--**	**PP**	**Yes**	**12762**	
1785	544	--	--	CP	No	12763	
1659	506	--	--	CP	No	12764	
1592	**485**	**--**	**--**	**CP**	**Yes**	**12765**	
1633	498	--	--	CP	No	12766	
1537	**468**	**--**	**--**	**PP**	**Yes**	**12767**	
1585	**483**	**--**	**--**	**CP**	**Yes**	**12768**	
1605	489	--	--	CP	No	12769	
1561	**476**	**--**	**--**	**CP**	**Yes**	**12770**	
1542	**470**	**--**	**--**	**PP**	**Yes**	**12771**	

Target:	**6055-T651**	Date:	**3/5/2013**
Plate Number:	**521-802**	Location:	**EF 106**
Thickness, in:	**0.749**		
Thickness, mm:	**19.02**		
Hardness, BHN:	**128**		
Obliquity:	**30°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2001 ft/s**	Number of Shots:	**6**
Std Dev:	**32 ft/s**	Spread:	**78 ft/s**
ZMR:	**39 ft/s**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
2048	**624**	**--**	**--**	**CP**	**Yes**	**12388**	
1973	**601**	**--**	**--**	**PP**	**Yes**	**12389**	
2028	**618**	**--**	**--**	**CP**	**Yes**	**12390**	
1979	**603**	**--**	**--**	**PP**	**Yes**	**12391**	
1905	581	--	--	PP	No	12392	
1970	**600**	**--**	**--**	**CP**	**Yes**	**12393**	
2009	**612**	**--**	**--**	**PP**	**Yes**	**12394**	

Target:	**6055-T651**	Date:	**3/7/2013**
Plate Number:	**521-812**	Location:	**EF 106**
Thickness, in:	**0.751**		
Thickness, mm:	**19.08**		
Hardness, BHN:	**126**		
Obliquity:	**30°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1998 ft/s**	Number of Shots:	**6**
Std Dev:	**33 ft/s**	Spread:	**76 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1954	**596**	**--**	**--**	**PP**	**Yes**	**12395**	
2046	624	--	--	CP	No	12396	
2030	**619**	**--**	**--**	**CP**	**Yes**	**12397**	
1969	**600**	**--**	**--**	**PP**	**Yes**	**12398**	
2029	**618**	**--**	**--**	**CP**	**Yes**	**12399**	
2022	**616**	**--**	**--**	**CP**	**Yes**	**12400**	
1982	**604**	**--**	**--**	**PP**	**Yes**	**12401**	

Target:	**6055-T651**	Date:	**3/7/2013**
Plate Number:	**521-812**	Location:	**EF 106**
Thickness, in:	**0.751**		
Thickness, mm:	**19.08**		
Hardness, BHN:	**126**		
Obliquity:	**30°**		
Projectile:	**0.30 cal Kit**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2016 ft/s**		Number of Shots:	**4**
Std Dev:	**25 ft/s**		Spread:	**53 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2075	632	--	--	CP	No	12402	
1883	574	--	--	PP	No	12403	
1863	568	--	--	PP	No	12404	
2004	**611**	**--**	**--**	**PP**	**Yes**	**12405**	
2053	**626**	**--**	**--**	**CP**	**Yes**	**12406**	
2008	**612**	**--**	**--**	**CP**	**Yes**	**12407**	
2000	**610**	**--**	**--**	**PP**	**Yes**	**12408**	

Target:	**6055-T651**	Date:	**3/4/2013**
Plate Number:	**521-802**	Location:	**EF 106**
Thickness, in:	**0.749**		
Thickness, mm:	**19.02**		
Hardness, BHN:	**128**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1770 ft/s**	Number of Shots:	**6**
Std Dev:	**37 ft/s**	Spread:	**87 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1731	**528**	**--**	**--**	**PP**	**Yes**	**12382**	
1818	**554**	**--**	**--**	**CP**	**Yes**	**12383**	
1746	**532**	**--**	**--**	**PP**	**Yes**	**12384**	
1797	**548**	**--**	**--**	**CP**	**Yes**	**12385**	
1734	**528**	**--**	**--**	**PP**	**Yes**	**12386**	
1791	**546**	**--**	**--**	**CP**	**Yes**	**12387**	

Target:	**6055-T651**	Date:	**2/28/2013**
Plate Number:	**521-812**	Location:	**EF 106**
Thickness, in:	**0.751**		
Thickness, mm:	**19.08**		
Hardness, BHN:	**126**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1762 ft/s**		Number of Shots:	**4**
Std Dev:	**20 ft/s**		Spread:	**45 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1765	**538**	**--**	**--**	**PP**	**Yes**	**12369**	
1822	555	--	--	CP	No	12370	
1777	**542**	**--**	**--**	**CP**	**Yes**	**12371**	
1732	**528**	**--**	**--**	**PP**	**Yes**	**12372**	
1772	**540**	**--**	**--**	**CP**	**Yes**	**12373**	

Target:	**6055-T651**	Date:	**2/28/2013**
Plate Number:	**521-812**	Location:	**EF 106**
Thickness, in:	**0.751**		
Thickness, mm:	**19.08**		
Hardness, BHN:	**126**		
Obliquity:	**0°**		
Projectile:	**0.30 cal Kit**		
Velocity Measurement:	**Chrono**		

V_{50}:	**1743 ft/s**		Number of Shots:	**4**
Std Dev:	**21 ft/s**		Spread:	**44 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1808	551	--	--	CP	No	12374	
1686	514	--	--	PP	No	12375	
1613	492	--	--	PP	No	12376	
1766	**538**	--	--	**CP**	**Yes**	**12377**	
1722	**525**	--	--	**PP**	**Yes**	**12378**	
1755	**535**	--	--	**CP**	**Yes**	**12379**	
1677	511	--	--	PP	No	12380	
1729	**527**	--	--	**PP**	**Yes**	**12381**	

Target:	**6055-T651**	Date:	**2/26/2013**
Plate Number:	**521-822**	Location:	**EF 106**
Thickness, in:	**0.994**		
Thickness, mm:	**25.25**		
Hardness, BHN:	**118**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2028 ft/s**	Number of Shots:	**6**
Std Dev:	**34 ft/s**	Spread:	**79 ft/s**
ZMR:	**28 ft/s**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1991	**607**	**--**	**--**	**PP**	**Yes**	**12348**	
2014	**614**	**--**	**--**	**PP**	**Yes**	**12349**	
2081	634	--	--	CP	No	12350	
1997	**609**	**--**	**--**	**CP**	**Yes**	**12351**	
2070	**631**	**--**	**--**	**CP**	**Yes**	**12352**	
2068	**630**	**--**	**--**	**CP**	**Yes**	**12353**	
2025	**617**	**--**	**--**	**PP**	**Yes**	**12354**	

Target:	**6055-T651**	Date:	**2/25/2013**
Plate Number:	**521-822**	Location:	**EF 106**
Thickness, in:	**0.994**		
Thickness, mm:	**25.25**		
Hardness, BHN:	**118**		
Obliquity:	**0°**		
Projectile:	**0.30 cal Kit**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2033 ft/s**		Number of Shots:	**4**
Std Dev:	**21 ft/s**		Spread:	**52 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2191	668	--	--	CP	No	12341	
2037	**621**	**--**	**--**	**CP**	**Yes**	**12342**	
1899	579	--	--	PP	No	12343	
2005	**611**	**--**	**--**	**PP**	**Yes**	**12344**	
1937	590	--	--	PP	No	12345	
2034	**620**	**--**	**--**	**PP**	**Yes**	**12346**	
2057	**627**	**--**	**--**	**CP**	**Yes**	**12347**	

Target:	**6055-T651**	Date:	**2/26/2013**
Plate Number:	**521-832**	Location:	**EF 106**
Thickness, in:	**1.011**		
Thickness, mm:	**25.68**		
Hardness, BHN:	**124**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2079 ft/s**		Number of Shots:	**6**
Std Dev:	**31 ft/s**		Spread:	**83 ft/s**
ZMR:	**17 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2021	616	--	--	PP	No	12355	
2114	**644**	--	--	**CP**	**Yes**	**12356**	
2106	**642**	--	--	**CP**	**Yes**	**12357**	
2031	**619**	--	--	**PP**	**Yes**	**12358**	
2011	613	--	--	PP	No	12359	
2062	**628**	--	--	**PP**	**Yes**	**12360**	
2072	**632**	--	--	**CP**	**Yes**	**12361**	
2089	**637**	--	--	**PP**	**Yes**	**12362**	

Target:	**6055-T651**	Date:	**2/27/2013**
Plate Number:	**521-842**	Location:	**EF 106**
Thickness, in:	**0.999**		
Thickness, mm:	**25.37**		
Hardness, BHN:	**124**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2067 ft/s**		Number of Shots:	**4**
Std Dev:	**25 ft/s**		Spread:	**55 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2120	646	--	--	CP	No	12363	
1977	603	--	--	PP	No	12364	
2037	**621**	**--**	**--**	**PP**	**Yes**	**12365**	
2056	**627**	**--**	**--**	**PP**	**Yes**	**12366**	
2081	**634**	**--**	**--**	**CP**	**Yes**	**12367**	
2092	**638**	**--**	**--**	**CP**	**Yes**	**12368**	

Target:	**6055-T651**	Date:	**3/12/2013**
Plate Number:	**521-871**	Location:	**EF 106**
Thickness, in:	**1.495**		
Thickness, mm:	**37.97**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2618 ft/s**		Number of Shots:	**4**
Std Dev:	**17 ft/s**		Spread:	**38 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2562	781	--	--	PP	No	12415	
2635	**803**	**--**	**--**	**CP**	**Yes**	**12416**	
2597	**792**	**--**	**--**	**PP**	**Yes**	**12417**	
2612	**796**	**--**	**--**	**PP**	**Yes**	**12418**	
2626	**800**	**--**	**--**	**CP**	**Yes**	**12419**	

Target:	**6055-T651**	Date:	**3/11/2013**
Plate Number:	**521-871**	Location:	**EF 106**
Thickness, in:	**1.495**		
Thickness, mm:	**37.97**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.30 cal Kit**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2626 ft/s**		Number of Shots:	**4**
Std Dev:	**28 ft/s**		Spread:	**55 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2757	840	--	--	CP	No	12409	
2711	826	--	--	CP	No	12410	
2600	**792**	**--**	**--**	**PP**	**Yes**	**12411**	
2655	**809**	**--**	**--**	**CP**	**Yes**	**12412**	
2603	**793**	**--**	**--**	**PP**	**Yes**	**12413**	
2645	**806**	**--**	**--**	**CP**	**Yes**	**12414**	

Target:	**6055-T651**	Date:	**3/12/2013**
Plate Number:	**521-872**	Location:	**EF 106**
Thickness, in:	**1.495**		
Thickness, mm:	**37.97**		
Hardness, BHN:	**121**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2585 ft/s**		Number of Shots:	**4**
Std Dev:	**26 ft/s**		Spread:	**53 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2654	809	--	--	CP	No	12420	
2546	**776**	--	--	**PP**	**Yes**	**12421**	
2621	799	--	--	CP	No	12422	
2599	**792**	--	--	**PP**	**Yes**	**12423**	
2594	**791**	--	--	**CP**	**Yes**	**12424**	
2599	**792**	--	--	**CP**	**Yes**	**12425**	

Target:	**6055-T651**	Date:	**3/13/2013**
Plate Number:	**521-881**	Location:	**EF 106**
Thickness, in:	**1.497**		
Thickness, mm:	**38.02**		
Hardness, BHN:	**118**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2634 ft/s**		Number of Shots:	**6**
Std Dev:	**28 ft/s**		Spread:	**78 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2587	**788**	**--**	**--**	**PP**	**Yes**	**12426**	
2631	**802**	**--**	**--**	**PP**	**Yes**	**12427**	
2702	824	--	--	CP	No	12428	
2665	**812**	**--**	**--**	**CP**	**Yes**	**12429**	
2642	**805**	**--**	**--**	**CP**	**Yes**	**12430**	
2659	**810**	**--**	**--**	**CP**	**Yes**	**12431**	
2621	**799**	**--**	**--**	**PP**	**Yes**	**12432**	

Target:	**6055-T651**	Date:	**3/13/2013**
Plate Number:	**521-882**	Location:	**EF 106**
Thickness, in:	**1.500**		
Thickness, mm:	**38.10**		
Hardness, BHN:	**121**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2654 ft/s**	Number of Shots:	**4**
Std Dev:	**25 ft/s**	Spread:	**58 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
2641	**805**	**--**	**--**	**PP**	**Yes**	**12433**	
2723	830	--	--	CP	No	12434	
2689	**820**	**--**	**--**	**CP**	**Yes**	**12435**	
2654	**809**	**--**	**--**	**CP**	**Yes**	**12436**	
2563	781	--	--	PP	No	12437	
2631	**802**	**--**	**--**	**PP**	**Yes**	**12438**	

Target:	**6055-T651**	Date:	**6/11/2013**
Plate Number:	**521-892**	Location:	**EF 106**
Thickness, in:	**1.498**		
Thickness, mm:	**38.05**		
Hardness, BHN:	**109**		
Obliquity:	**0°**		
Projectile:	**0.30 cal APM2**		
Velocity Measurement:	**Chrono**		

V_{50}:	**2651 ft/s**		Number of Shots:	**6**
Std Dev:	**27 ft/s**		Spread:	**76 ft/s**
ZMR:	**25 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2661	**811**	**--**	**--**	**PP**	**Yes**	**12753**	
2803	854	--	--	CP	No	12754	
2711	826	--	--	CP	No	12755	
2683	**818**	**--**	**--**	**CP**	**Yes**	**12756**	
2607	**795**	**--**	**--**	**PP**	**Yes**	**12757**	
2670	**814**	**--**	**--**	**CP**	**Yes**	**12758**	
2636	**803**	**--**	**--**	**CP**	**Yes**	**12759**	
2649	**807**	**--**	**--**	**PP**	**Yes**	**12760**	

0.50-cal APM2

Target:	**6055-T651**	Date:	**4/8/2013**
Plate Number:	**521-871**	Location:	**EF 110G**
Thickness, in:	**1.493**		
Thickness, mm:	**37.92**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**1918 ft/s**	Number of Shots:	**4**
Std Dev:	**24 ft/s**	Spread:	**47 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1901	**579**	**-0.50**	**-0.25**	**PP**	**Yes**	**14347**	
1942	**592**	**-0.50**	**0.25**	**CP**	**Yes**	**14348**	
1935	**590**	**-0.50**	**-0.25**	**CP**	**Yes**	**14349**	
1895	**578**	**0.25**	**0.00**	**PP**	**Yes**	**14350**	

Target:	**6055-T651**	Date:	**4/9/2013**
Plate Number:	**521-872**	Location:	**EF 110G**
Thickness, in:	**1.494**		
Thickness, mm:	**37.95**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**1915 ft/s**		Number of Shots:	**4**
Std Dev:	**24 ft/s**		Spread:	**56 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1941	**592**	**0.25**	**0.00**	**CP**	**Yes**	**14356**	
1927	**587**	**0.25**	**-0.25**	**CP**	**Yes**	**14357**	
1885	**575**	**0.00**	**-0.50**	**PP**	**Yes**	**14358**	
1907	**581**	**0.00**	**0.00**	**PP**	**Yes**	**14359**	

Target:	**6055-T651**	Date:	**4/4/2013**
Plate Number:	**521-881**	Location:	**EF 110G**
Thickness, in:	**1.497**		
Thickness, mm:	**38.02**		
Hardness, BHN:	**121**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**1917 ft/s**		Number of Shots:	**4**
Std Dev:	**29 ft/s**		Spread:	**57 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1989	606	-0.25	-0.25	CP	No	14342	
1888	**575**	**0.00**	**0.00**	**PP**	**Yes**	**14343**	
1945	**593**	**0.00**	**0.00**	**CP**	**Yes**	**14344**	
1939	**591**	**-0.25**	**-0.25**	**CP**	**Yes**	**14345**	
1896	**578**	**0.00**	**0.00**	**PP**	**Yes**	**14346**	

Target:	**6055-T651**	Date:	**4/3/2013**
Plate Number:	**521-882**	Location:	**EF 110G**
Thickness, in:	**1.499**		
Thickness, mm:	**38.07**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**1969 ft/s**		Number of Shots:	**4**
Std Dev:	**28 ft/s**		Spread:	**59 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2271	692	0.00	0.75	CP	No	14333	
1986	**605**	**0.00**	**0.25**	**CP**	**Yes**	**14334**	
1882	574	-0.25	0.00	PP	No	14335	
1915	584	0.25	-0.75	PP	No	14336	
1914	583	0.25	0.00	PP	No	14337	
1940	**591**	**-0.75**	**0.25**	**PP**	**Yes**	**14338**	
2021	616	0.00	-0.25	CP	No	14339	
1950	**594**	**0.25**	**0.00**	**PP**	**Yes**	**14340**	
1999	**609**	**0.00**	**0.00**	**CP**	**Yes**	**14341**	

Target:	**6055-T651**	Date:	**6/25/2013**
Plate Number:	**521-892**	Location:	**EF 108**
Thickness, in:	**1.498**		
Thickness, mm:	**38.05**		
Hardness, BHN:	**109**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**1977 ft/s**		Number of Shots:	**6**
Std Dev:	**36 ft/s**		Spread:	**87 ft/s**
ZMR:	**12 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1742	531	--	--	PP	No	11437	
1956	**596**	**--**	**--**	**CP**	**Yes**	**11438**	
1851	564	--	--	PP	No	11439	
1928	588	--	--	PP	No	11440	
1945	**593**	**--**	**--**	**PP**	**Yes**	**11441**	
1947	**593**	**--**	**--**	**PP**	**Yes**	**11442**	
1674	510	--	--	PP	No	11443	
2011	**613**	**--**	**--**	**CP**	**Yes**	**11444**	
1968	**600**	**--**	**--**	**PP**	**Yes**	**11445**	
1526	465	--	--	PP	No	11446	
1484	452	--	--	PP	No	11447	
1611	491	--	--	PP	No	11448	
1679	512	--	--	PP	No	11449	
1903	580	--	--	PP	No	11450	
2032	**619**	**--**	**--**	**CP**	**Yes**	**11451**	

Target:	**6055-T651**	Date:	**4/12/2013**
Plate Number:	**521-901**	Location:	**EF 110G**
Thickness, in:	**1.977**		
Thickness, mm:	**50.22**		
Hardness, BHN:	**101**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2254 ft/s**		Number of Shots:	**4**
Std Dev:	**15 ft/s**		Spread:	**33 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2343	714	0.25	-0.50	CP	No	14373	
2313	705	0.25	0.00	CP	No	14374	
2260	**689**	**-1.00**	**0.25**	**CP**	**Yes**	**14375**	
2212	674	-0.25	0.00	PP	No	14376	
2239	**682**	**0.00**	**0.75**	**PP**	**Yes**	**14377**	
2243	**684**	**0.00**	**0.00**	**PP**	**Yes**	**14378**	
2272	**692**	**0.25**	**-0.25**	**CP**	**Yes**	**14379**	

Target:	**6055-T651**	Date:	**6/19/2013**
Plate Number:	**521-902**	Location:	**EF 108**
Thickness, in:	**1.790**		
Thickness, mm:	**45.47**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2251 ft/s**		Number of Shots:	**4**
Std Dev:	**29 ft/s**		Spread:	**58 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2296	700	--	--	CP	No	11431	
2277	**694**	--	--	**CP**	**Yes**	**11432**	
2151	656	--	--	PP	No	11433	
2219	**676**	--	--	**PP**	**Yes**	**11434**	
2275	**693**	--	--	**CP**	**Yes**	**11435**	
2233	**681**	--	--	**PP**	**Yes**	**11436**	

Target:	**6055-T651**	Date:	**4/11/2013**
Plate Number:	**521-911**	Location:	**EF 110G**
Thickness, in:	**1.999**		
Thickness, mm:	**50.77**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2309 ft/s**		Number of Shots:	**4**
Std Dev:	**16 ft/s**		Spread:	**39 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2289	**698**	**0.25**	**0.25**	**PP**	**Yes**	**14368**	
2287	697	0.25	0.00	PP	No	14369	
2312	**705**	**0.25**	**-0.25**	**CP**	**Yes**	**14370**	
2305	**703**	**0.25**	**0.00**	**PP**	**Yes**	**14371**	
2328	**710**	**0.25**	**0.00**	**CP**	**Yes**	**14372**	

Target:	**6055-T651**	Date:	**4/11/2013**
Plate Number:	**521-921**	Location:	**EF 110G**
Thickness, in:	**2.004**		
Thickness, mm:	**50.90**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2286 ft/s**		Number of Shots:	**4**
Std Dev:	**19 ft/s**		Spread:	**41 ft/s**
ZMR:	**28 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2295	**699**	**0.00**	**-0.25**	**PP**	**Yes**	**14360**	
2350	716	-0.50	0.00	CP	No	14361	
2335	712	0.00	0.00	CP	No	14362	
2308	**703**	**0.25**	**0.00**	**CP**	**Yes**	**14363**	
2314	705	0.00	0.00	CP	No	14364	
2267	**691**	**0.00**	**-0.25**	**CP**	**Yes**	**14365**	
2228	679	0.00	0.00	PP	No	14366	
2273	**693**	**0.00**	**0.00**	**PP**	**Yes**	**14367**	

Target:	**6055-T651**	Date:	**6/12/2013**
Plate Number:	**521-922**	Location:	**EF 108**
Thickness, in:	**1.980**		
Thickness, mm:	**50.29**		
Hardness, BHN:	**116**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2278 ft/s**		Number of Shots:	**4**
Std Dev:	**21 ft/s**		Spread:	**49 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2325	709	--	--	CP	No	11423	
2093	638	--	--	PP	No	11424	
2168	661	--	--	PP	No	11425	
2253	**687**	**--**	**--**	**PP**	**Yes**	**11426**	
2338	713	--	--	CP	No	11427	
2302	**702**	**--**	**--**	**CP**	**Yes**	**11428**	
2272	**692**	**--**	**--**	**PP**	**Yes**	**11429**	
2285	**696**	**--**	**--**	**CP**	**Yes**	**11430**	

Target:	**6055-T651**	Date:	**4/16/2013**
Plate Number:	**521-941**	Location:	**EF 110G**
Thickness, in:	**2.500**		
Thickness, mm:	**63.50**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2615 ft/s**	Number of Shots:	**4**
Std Dev:	**24 ft/s**	Spread:	**57 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
2660	811	0.00	1.00	CP	No	14387	
2616	**797**	**0.25**	**0.00**	**PP**	**Yes**	**14388**	
2667	813	0.50	0.25	CP	No	14389	
2583	**787**	**0.25**	**0.00**	**PP**	**Yes**	**14390**	
2620	**799**	**0.00**	**-0.25**	**CP**	**Yes**	**14391**	
2640	**805**	**0.50**	**0.25**	**CP**	**Yes**	**14392**	

Target:	**6055-T651**	Date:	**4/15/2013**
Plate Number:	**521-942**	Location:	**EF 110G**
Thickness, in:	**2.487**		
Thickness, mm:	**63.17**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2671 ft/s**		Number of Shots:	**4**
Std Dev:	**27 ft/s**		Spread:	**58 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2622	799	0.00	0.25	PP	No	14380	
2758	841	0.00	-0.50	CP	No	14381	
2706	**825**	**1.50**	**-0.25**	**CP**	**Yes**	**14382**	
2648	**807**	**0.25**	**0.50**	**PP**	**Yes**	**14383**	
2678	**816**	**0.00**	**0.00**	**CP**	**Yes**	**14384**	
2662	811	0.00	0.00	X	No	14385	Projectile Hit Clamp - No Test
2651	**808**	**0.25**	**0.75**	**PP**	**Yes**	**14386**	

Target:	**6055-T651**	Date:	**6/11/2013**
Plate Number:	**521-951**	Location:	**EF 108**
Thickness, in:	**2.918**		
Thickness, mm:	**74.12**		
Hardness, BHN:	**124**		
Obliquity:	**0°**		
Projectile:	**0.50 cal APM2**		
Velocity Measurement:	**Xray**		

V_{50}:	**2974 ft/s**		Number of Shots:	**4**
Std Dev:	**25 ft/s**		Spread:	**57 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2893	882	--	--	PP	No	11418	
3009	**917**	--	--	**CP**	**Yes**	**11419**	
2959	**902**	--	--	**PP**	**Yes**	**11420**	
2975	**907**	--	--	**CP**	**Yes**	**11421**	
2952	**900**	--	--	**PP**	**Yes**	**11422**	

Target:	**6055-T651**	Date:	**6/6/2013**
Plate Number:	**521-951**	Location:	**EF 108**
Thickness, in:	**2.918**		
Thickness, mm:	**74.12**		
Hardness, BHN:	**124**		
Obliquity:	**0°**		
Projectile:	**14.5 mm BS41**		
Velocity Measurement:	**Xray**		

V_{50}:	**2752 ft/s**		Number of Shots:	**6**
Std Dev:	**32 ft/s**		Spread:	**84 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2508	764	--	--	PP	No	11410	
2604	794	--	--	PP	No	11411	
2793	**851**	**--**	**--**	**CP**	**Yes**	**11412**	
2709	**826**	**--**	**--**	**PP**	**Yes**	**11413**	
2722	**830**	**--**	**--**	**PP**	**Yes**	**11414**	
2757	**840**	**--**	**--**	**CP**	**Yes**	**11415**	
2752	**839**	**--**	**--**	**PP**	**Yes**	**11416**	
2779	**847**	**--**	**--**	**CP**	**Yes**	**11417**	

0.50-cal FSP

Target:	**6055-T651**	Date:	**1/16/2013**
Plate Number:	**521-802**	Location:	**EF 110G**
Thickness, in:	**0.751**		
Thickness, mm:	**19.08**		
Hardness, BHN:	**126**		
Obliquity:	**0°**		
Projectile:	**0.50 cal FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**1888 ft/s**	Number of Shots:	**4**
Std Dev:	**13 ft/s**	Spread:	**24 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1875	**571**	**-0.25**	**0.00**	**PP**	**Yes**	**14185**	
1958	597	0.25	-0.25	CP	No	14186	
1992	607	0.00	0.25	CP	No	14187	
1967	600	0.00	0.25	CP	No	14188	
1967	600	-0.25	-0.25	CP	No	14189	
1899	**579**	**-0.50**	**-0.25**	**CP**	**Yes**	**14190**	
1980	603	-0.25	-0.50	CP	No	14191	
1866	569	-0.25	-0.50	PP	No	14192	
1877	**572**	**-0.25**	**-0.25**	**PP**	**Yes**	**14193**	
1899	**579**	**0.25**	**0.75**	**CP**	**Yes**	**14194**	

Target:	**6055-T651**	Date:	**1/15/2013**
Plate Number:	**521-812**	Location:	**EF 110G**
Thickness, in:	**0.753**		
Thickness, mm:	**19.13**		
Hardness, BHN:	**126**		
Obliquity:	**0°**		
Projectile:	**0.50 cal FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**1929 ft/s**		Number of Shots:	**4**
Std Dev:	**19 ft/s**		Spread:	**46 ft/s**
ZMR:	**46 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1988	606	0.50	-0.50	CP	No	14177	
1903	**580**	**0.50**	**0.25**	**CP**	**Yes**	**14178**	
1793	546	0.00	0.00	PP	No	14179	
1818	554	0.50	-0.25	PP	No	14180	
1803	550	-0.25	0.25	PP	No	14181	
1933	**589**	**0.50**	**-0.50**	**PP**	**Yes**	**14182**	
1949	**594**	**0.50**	**0.25**	**PP**	**Yes**	**14183**	
1932	**589**	**0.00**	**0.25**	**CP**	**Yes**	**14184**	

Target:	**6055-T651**	Date:	**1/9/2013**
Plate Number:	**521-822**	Location:	**EF 110G**
Thickness, in:	**0.991**		
Thickness, mm:	**25.17**		
Hardness, BHN:	**116**		
Obliquity:	**0°**		
Projectile:	**0.50 cal FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3037 ft/s**		Number of Shots:	**4**
Std Dev:	**28 ft/s**		Spread:	**60 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3431	1046	-0.50	1.00	CP	No	14149	
3455	1053	1.50	-1.00	CP	No	14150	
3257	993	-2.50	-1.50	CP	No	14151	
3324	1013	-0.25	-0.50	CP	No	14152	
3001	**915**	**0.00**	**2.00**	**PP**	**Yes**	**14153**	
3072	936	-0.75	-1.25	CP	No	14154	
3069	935	-0.75	1.00	CP	No	14155	
2971	906	-0.25	0.75	PP	No	14156	
3026	**922**	**-0.50**	**0.50**	**PP**	**Yes**	**14157**	
3058	**932**	**-0.75**	**-0.50**	**CP**	**Yes**	**14158**	
3061	**933**	**0.00**	**0.25**	**CP**	**Yes**	**14159**	

Target:	**6055-T651**	Date:	**1/14/2013**
Plate Number:	**521-832**	Location:	**EF 110G**
Thickness, in:	**1.010**		
Thickness, mm:	**25.65**		
Hardness, BHN:	**118**		
Obliquity:	**0°**		
Projectile:	**0.50 cal FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3114 ft/s**		Number of Shots:	**4**
Std Dev:	**27 ft/s**		Spread:	**56 ft/s**
ZMR:	**29 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3032	924	0.00	0.00	PP	No	14171	
3079	**938**	**0.00**	**0.50**	**PP**	**Yes**	**14172**	
3106	**947**	**0.25**	**0.25**	**CP**	**Yes**	**14173**	
2964	903	-0.25	-0.25	PP	No	14174	
3134	**955**	**0.00**	**0.75**	**CP**	**Yes**	**14175**	
3135	**956**	**0.00**	**0.50**	**PP**	**Yes**	**14176**	

Target:	**6055-T651**	Date:	**1/10/2013**
Plate Number:	**521-842**	Location:	**EF 110G**
Thickness, in:	**0.998**		
Thickness, mm:	**25.35**		
Hardness, BHN:	**124**		
Obliquity:	**0°**		
Projectile:	**0.50 cal FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3012 ft/s**		Number of Shots:	**6**
Std Dev:	**28 ft/s**		Spread:	**76 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2992	**912**	**-0.75**	**0.50**	**PP**	**Yes**	**14160**	
2960	902	0.00	0.50	PP	No	14161	
2958	902	0.00	0.75	PP	No	14162	
2919	890	-0.75	0.25	PP	No	14163	
2982	**909**	**0.50**	**0.75**	**PP**	**Yes**	**14164**	
2996	**913**	**-0.25**	**0.25**	**PP**	**Yes**	**14165**	
3146	959	0.00	0.50	CP	No	14166	
3011	**918**	**-3.25**	**5.75**	**CP**	**Yes**	**14167**	**6.6 gamma but complete**
3058	**932**	**-0.25**	**0.50**	**CP**	**Yes**	**14168**	
3090	942	0.75	-0.25	CP	No	14169	
3031	**924**	**-0.25**	**0.50**	**CP**	**Yes**	**14170**	

20-mm FSP

Target:	**6055-T651**	Date:	**3/28/2013**
Plate Number:	**521-822**	Location:	**EF 110E**
Thickness, in:	**0.991**		
Thickness, mm:	**25.17**		
Hardness, BHN:	**116**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**1449 ft/s**	Number of Shots:	**6**
Std Dev:	**26 ft/s**	Spread:	**67 ft/s**
ZMR:	**32 ft/s**		

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1640	500	0.00	0.25	CP	No	1962	
1428	**435**	**-0.25**	**-1.25**	**PP**	**Yes**	**1963**	
1477	**450**	**0.00**	**-2.50**	**PP**	**Yes**	**1964**	
1496	456	-0.25	-0.25	CP	No	1965	
1495	456	-1.00	-0.75	CP	No	1966	
1460	**445**	**0.00**	**-1.75**	**CP**	**Yes**	**1967**	
1473	**449**	**-0.50**	**-1.25**	**CP**	**Yes**	**1968**	
1445	**440**	**0.00**	**-0.50**	**CP**	**Yes**	**1969**	
1410	**430**	**-0.75**	**0.25**	**PP**	**Yes**	**1970**	

Target:	**6055-T651**	Date:	**4/1/2013**
Plate Number:	**521-832**	Location:	**EF 110E**
Thickness, in:	**1.002**		
Thickness, mm:	**25.45**		
Hardness, BHN:	**114**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**1372 ft/s**		Number of Shots:	**4**
Std Dev:	**16 ft/s**		Spread:	**37 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
1458	444	0.00	-0.50	CP	No	1971	
1388	**423**	**-0.50**	**0.25**	**CP**	**Yes**	**1972**	
1366	**416**	**-0.50**	**-0.75**	**PP**	**Yes**	**1973**	
1381	**421**	**0.25**	**-0.50**	**CP**	**Yes**	**1974**	
1351	**412**	**0.25**	**1.00**	**PP**	**Yes**	**1975**	

Target:	**6055-T651**	Date:	**4/1/2013**
Plate Number:	**521-842**	Location:	**EF 110E**
Thickness, in:	**1.000**		
Thickness, mm:	**25.40**		
Hardness, BHN:	**121**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**1384 ft/s**	Number of Shots:	**4**
Std Dev:	**17 ft/s**	Spread:	**39 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
1363	**415**	**0.25**	**0.50**	**PP**	**Yes**	**1976**	
1391	**424**	**0.00**	**0.00**	**PP**	**Yes**	**1977**	
1379	**420**	**-0.50**	**-0.50**	**CP**	**Yes**	**1978**	
1402	**427**	**-0.50**	**-2.00**	**CP**	**Yes**	**1979**	

Target:	**6055-T651**	Date:	**4/4/2013**
Plate Number:	**521-871**	Location:	**EF 110E**
Thickness, in:	**1.493**		
Thickness, mm:	**37.92**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**2661 ft/s**	Number of Shots:	**4**
Std Dev:	**26 ft/s**	Spread:	**60 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
2698	**822**	**-0.50**	**1.25**	**CP**	**Yes**	**1990**	
2630	802	0.00	0.25	PP	No	1991	
2638	**804**	**-0.50**	**0.75**	**PP**	**Yes**	**1992**	
2657	**810**	**0.00**	**0.00**	**CP**	**Yes**	**1993**	
2649	**807**	**0.25**	**0.25**	**PP**	**Yes**	**1994**	

Target:	**6055-T651**	Date:	**4/3/2013**
Plate Number:	**521-881**	Location:	**EF 110E**
Thickness, in:	**1.497**		
Thickness, mm:	**38.02**		
Hardness, BHN:	**121**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**2681 ft/s**		Number of Shots:	**4**
Std Dev:	**12 ft/s**		Spread:	**29 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3029	923	0.25	0.25	CP	No	1980	
2981	909	-0.25	0.00	CP	No	1981	
2907	886	0.00	0.25	CP	No	1982	
2734	833	-0.50	1.25	CP	No	1983	
2611	796	-0.25	0.50	PP	No	1984	
2668	**813**	**0.00**	**0.00**	**PP**	**Yes**	**1985**	
2680	**817**	**-0.75**	**1.00**	**CP**	**Yes**	**1986**	
2679	**817**	**-0.25**	**1.75**	**PP**	**Yes**	**1987**	
2663	812	-0.25	-1.50	PP	No	1988	
2697	**822**	**0.00**	**0.25**	**CP**	**Yes**	**1989**	

Target:	**6055-T651**	Date:	**4/10/2013**
Plate Number:	**521-882**	Location:	**EF 110E**
Thickness, in:	**1.493**		
Thickness, mm:	**37.92**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**2565 ft/s**		Number of Shots:	**6**
Std Dev:	**24 ft/s**		Spread:	**65 ft/s**
ZMR:	**31 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2637	804	-0.75	0.75	CP	No	1995	
2585	**788**	**0.00**	**-0.25**	**PP**	**Yes**	**1996**	
2599	792	-0.50	0.00	CP	No	1997	
2610	795	-0.25	1.00	CP	No	1998	
2588	**789**	**0.00**	**-0.50**	**CP**	**Yes**	**1999**	
2593	790	-0.75	1.00	CP	No	2000	
2602	793	-1.25	0.75	CP	No	2001	
2568	**783**	**-0.50**	**-0.25**	**CP**	**Yes**	**2002**	
2554	**778**	**0.00**	**0.00**	**CP**	**Yes**	**2003**	
2523	**769**	**0.00**	**0.00**	**PP**	**Yes**	**2004**	
2571	**784**	**-0.50**	**0.00**	**PP**	**Yes**	**14430**	

Target:	**6055-T651**	Date:	**10/30/2013**
Plate Number:	**521-892**	Location:	**EF 110G**
Thickness, in:	**1.500**		
Thickness, mm:	**38.10**		
Hardness, BHN:	**112**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**2432 ft/s**		Number of Shots:	**4**
Std Dev:	**25 ft/s**		Spread:	**54 ft/s**
ZMR:	**9 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
2716	828	0.00	0.00	CP	No	14676	
2655	809	0.00	0.00	CP	No	14677	
2553	778	-0.25	0.00	CP	No	14678	
2571	784	0.00	-0.50	CP	No	14679	
2496	761	-0.50	-0.50	CP	No	14680	
2372	723	-0.25	-0.25	PP	No	14681	
2414	**736**	**-0.50**	**0.00**	**CP**	**Yes**	**14682**	
2423	**738**	**0.00**	**-0.25**	**PP**	**Yes**	**14683**	
2422	**738**	**0.50**	**-0.25**	**PP**	**Yes**	**14684**	
2468	**752**	**0.00**	**-0.50**	**CP**	**Yes**	**14685**	

Target:	**6055-T651**	Date:	**4/25/2013**
Plate Number:	**521-901**	Location:	**EF 110G**
Thickness, in:	**1.997**		
Thickness, mm:	**50.72**		
Hardness, BHN:	**101**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3985 ft/s**	Number of Shots:	**6**
Std Dev:	**30 ft/s**	Spread:	**78 ft/s**
ZMR:	**N/A**		

Striking Velocity (ft/s)	Striking Velocity (m/s)	Pitch (deg)	Yaw (deg)	Result (PP/CP)	Used for V_{50} (Yes/No)	Shot Number	Comments
3935	**1199**	**0.00**	**-0.25**	**PP**	**Yes**	**14417**	
4006	**1221**	**0.25**	**0.25**	**CP**	**Yes**	**14418**	
3979	**1213**	**0.25**	**-0.50**	**PP**	**Yes**	**14419**	
3969	**1210**	**-0.25**	**0.00**	**PP**	**Yes**	**14420**	
4010	**1222**	**0.25**	**-0.50**	**CP**	**Yes**	**14421**	
4013	**1223**	**-0.25**	**0.25**	**CP**	**Yes**	**14422**	

Target:	**6055-T651**	Date:	**10/24/2013**
Plate Number:	**521-902**	Location:	**EF 110G**
Thickness, in:	**1.984**		
Thickness, mm:	**50.39**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3935 ft/s**		Number of Shots:	**4**
Std Dev:	**31 ft/s**		Spread:	**60 ft/s**
ZMR:	**48 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3962	**1208**	**0.00**	**-0.25**	**PP**	**Yes**	**14653**	
4001	1219	-0.25	0.25	CP	No	14654	
3960	**1207**	**0.00**	**0.50**	**CP**	**Yes**	**14655**	
3902	**1189**	**0.00**	**-0.50**	**PP**	**Yes**	**14656**	
3914	**1193**	**-0.75**	**0.75**	**CP**	**Yes**	**14657**	

Target:	**6055-T651**	Date:	**4/22/2013**
Plate Number:	**521-911**	Location:	**EF 110G**
Thickness, in:	**1.999**		
Thickness, mm:	**50.77**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3943 ft/s**		Number of Shots:	**4**
Std Dev:	**24 ft/s**		Spread:	**57 ft/s**
ZMR:	**N/A**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3844	1172	0.25	0.50	PP	No	14402	
3883	1183	0.25	0.00	PP	No	14403	
3914	**1193**	**-0.50**	**-0.25**	**PP**	**Yes**	**14404**	
3953	**1205**	**-0.25**	**-1.00**	**CP**	**Yes**	**14405**	
3935	**1199**	**0.00**	**-0.25**	**PP**	**Yes**	**14406**	
3971	**1210**	**-0.25**	**0.75**	**CP**	**Yes**	**14407**	

Target:	**6055-T651**	Date:	**4/18/2013**
Plate Number:	**521-921**	Location:	**EF 110G**
Thickness, in:	**2.004**		
Thickness, mm:	**50.90**		
Hardness, BHN:	**107**		
Obliquity:	**0°**		
Projectile:	**20-mm FSP**		
Velocity Measurement:	**Xray**		

V_{50}:	**3836 ft/s**		Number of Shots:	**4**
Std Dev:	**16 ft/s**		Spread:	**39 ft/s**
ZMR:	**2 ft/s**			

Striking Velocity		Pitch	Yaw	Result	Used for V_{50}	Shot	Comments
(ft/s)	(m/s)	(deg)	(deg)	(PP/CP)	(Yes/No)	Number	
3814	**1162**	**-0.25**	**-0.25**	**PP**	**Yes**	**14398**	
3840	**1170**	**0.00**	**0.00**	**PP**	**Yes**	**14399**	
3853	**1174**	**0.00**	**0.25**	**CP**	**Yes**	**14400**	
3838	**1170**	**0.00**	**0.00**	**CP**	**Yes**	**14401**	

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Appendix B. Additional Ballistic Test Data

This appendix appears in its original form, without editorial change.

The following tables list data collected by ATC.[7]

0.30 cal. APM2, 30° Obliquity Ballistic Performance

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		Ballistic Limit		Standard Deviation	
	mm	in	mm	in	kg/m^2	psf	m/s	fps	m/s	fps
521–802	19.05	0.75	19.05	0.750	51.67	10.58	592	1942	4	13
521–812	19.05	0.75	19.02	0.749	51.60	10.57	576	1889	7	24

0.30 cal. APM2, 0° Obliquity Ballistic Performance

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		Ballistic Limit		Standard Deviation	
	mm	in	mm	in	kg/m^2	psf	m/s	fps	m/s	fps
521–801	19.05	0.75	19.02	0.749	51.60	10.57	543	1780	9	29
521–811	19.05	0.75	19.05	0.750	51.67	10.58	532	1744	12	41
521–821	25.40	1.00	25.60	1.008	69.44	14.22	616	2022	8	26
521–822	25.40	1.00	25.60	1.008	69.44	14.22	603	1977	10	34
521–831	25.40	1.00	25.40	1.000	68.89	14.11	637	2089	3	11
521–841	25.40	1.00	25.53	1.005	69.24	14.18	628	2062	5	18
521–842	25.40	1.00	25.65	1.010	69.58	14.25	622	2042	10	32
521–852	31.75	1.25	31.50	1.240	85.42	17.50	694	2278	8	26
521–861	31.75	1.25	31.75	1.250	86.11	17.64	717	2354	7	22
521–872	38.10	1.50	37.72	1.485	102.30	20.95	785	2577	6	19
521–882	38.10	1.50	37.85	1.490	102.65	21.02	802	2630	5	18
521–892	38.10	1.50	37.85	1.490	102.65	21.02	796	2612	10	33

0.50 cal. APM2, 0° Obliquity Ballistic Performance

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		Ballistic Limit		Standard Deviation	
	mm	in	mm	in	kg/m^2	psf	m/s	fps	m/s	fps
521–801	19.05	0.75	19.02	0.749	51.60	10.57	420	1377	8	25
521–811	19.05	0.75	19.05	0.750	51.67	10.58	418	1373	8	25
521–901	50.80	2.00	49.78	1.960	135.03	27.66	681	2234	8	26
521–911	50.80	2.00	50.88	2.003	137.99	28.26	697	2286	7	24
521–921	50.80	2.00	51.05	2.010	138.47	28.36	699	2294	8	25
521–931	57.15	2.25	56.90	2.240	154.32	31.61	738	2423	8	27
521–941	63.50	2.50	63.32	2.493	171.74	35.18	785	2574	8	26
521–942	63.50	2.50	63.37	2.495	171.88	35.20	798	2619	5	16
521–951	76.20	3.00	76.28	3.003	206.88	42.37	902	2961	4	13

0.50 cal. FSP, 0° Obliquity Ballistic Performance

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		Ballistic Limit		Standard Deviation	
	mm	in	mm	in	kg/m^2	psf	m/s	fps	m/s	fps
521–771	22.23	0.88	22.23	0.875	60.28	12.35	765	2509	7	23
521–802	19.05	0.75	19.15	0.754	51.94	10.64	563	1848	8	25
521–812	19.05	0.75	19.15	0.754	51.94	10.64	573	1879	6	21
521–821	25.40	1.00	25.60	1.008	69.44	14.22	941	3086	8	26
521–822	25.40	1.00	25.04	0.986	67.93	13.91	911	2989	9	29
521–831	25.40	1.00	25.40	1.000	68.89	14.11	917	3008	4	14
521–832	25.40	1.00	25.40	1.000	68.89	14.11	922	3026	5	18
521–841	25.40	1.00	25.53	1.005	69.24	14.18	934	3066	10	32
521–842	25.40	1.00	25.17	0.991	68.27	13.98	904	2966	6	20

20 mm FSP, 0° Obliquity Ballistic Performance

Plate ID	Nominal Thickness		Actual Thickness		Areal Density		Ballistic Limit		Standard Deviation	
	mm	in	mm	in	kg/m^2	psf	m/s	fps	m/s	fps
521–821	25.40	1.00	25.60	1.008	69.44	14.22	436	1431	8	25
521–822	25.40	1.00	25.60	1.008	69.44	14.22	439	1440	9	30
521–831	25.40	1.00	25.40	1.000	68.89	14.11	426	1397	6	21
521–832	25.40	1.00	25.81	1.016	69.99	14.34	431	1414	7	22
521–841	25.40	1.00	25.53	1.005	69.24	14.18	414	1358	6	19
521–842	25.40	1.00	25.65	1.010	69.58	14.25	407	1336	7	23
521–852	31.75	1.25	31.50	1.240	85.42	17.50	578	1898	8	26
521–861	31.75	1.25	31.75	1.250	86.11	17.64	574	1882	7	23
521–872	38.10	1.50	37.72	1.485	102.30	20.95	799	2620	7	24
521–882	38.10	1.50	37.85	1.490	102.65	21.02	787	2583	10	33
521–892	38.10	1.50	37.85	1.490	102.65	21.02	758	2487	9	28

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List of Symbols, Abbreviations, and Acronyms

AA	aluminum alloy
AP	armor-piercing
ARL	US Army Research Laboratory
ATC	Aberdeen Test Center
CP	complete penetration
DAC	Defense Acquisition Challenge
EF	experimental facility
FSP	fragment-simulating projectile
IR	infrared
OSD	Office of the Secretary of Defense
PP	partial penetration

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